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# PATENT COOPERATION TREATY

# PCT

## INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

| Applicant's or agent's file reference<br>visc/MC03A32 | **FOR FURTHER ACTION** See Form PCT/IPEA/416 | |
|---|---|---|
| International application No.<br>PCT/IT2004/000153 | International filing date *(day/month/year)*<br>25.03.2004 | Priority date *(day/month/year)*<br>28.03.2003 |
| International Patent Classification (IPC) or national classification and IPC<br>G10H1/06, G10H5/00, G10H1/02 | | |
| Applicant<br>VISCOUNT INTERNATIONAL S.P.A. et al | | |

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 7 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. ☒ *sent to the applicant and to the International Bureau)* a total of 12 sheets, as follows:
      - ☒ sheets of the description, claims and/or drawings which have been amended and are the basis of this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
      - ☒ sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.

   b. ☐ *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing and/or tables related thereto, in computer readable form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).

4. This report contains indications relating to the following items:

| | | |
|---|---|---|
| ☒ | Box No. I | Basis of the opinion |
| ☐ | Box No. II | Priority |
| ☐ | Box No. III | Non-establishment of opinion with regard to novelty, inventive step and industrial applicability |
| ☐ | Box No. IV | Lack of unity of invention |
| ☒ | Box No. V | Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement |
| ☐ | Box No. VI | Certain documents cited |
| ☐ | Box No. VII | Certain defects in the international application |
| ☐ | Box No. VIII | Certain observations on the international application |

| Date of submission of the demand | Date of completion of this report |
|---|---|
| 25.10.2004 | 14.04.2005 |
| Name and mailing address of the international preliminary examining authority:<br>European Patent Office<br>D-80298 Munich<br>Tel. +49 89 2399 - 0 Tx: 523656 epmu d<br>Fax: +49 89 2399 - 4465 | Authorized Officer<br>Lecointe, M<br>Telephone No. +49 89 2399-5266 |

## Box No. I Basis of the report

1. With regard to the **language**, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.

   ☐ This report is based on translations from the original language into the following language , which is the language of a translation furnished for the purposes of:
   - ☒ international search (under Rules 12.3 and 23.1(b))
   - ☐ publication of the international application (under Rule 12.4)
   - ☐ international preliminary examination (under Rules 55.2 and/or 55.3)

2. With regard to the **elements*** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

**Description, Pages**

| | |
|---|---|
| 3, 4, 6-10, 12, 14, 15, 17 | as originally filed |
| 1, 2, 5, 11, 13, 16 | received on 24.11.2004 with letter of 23.11.2004 |

**Claims, Numbers**

| | |
|---|---|
| 1-10 | received on 24.11.2004 with letter of 23.11.2004 |

**Drawings, Sheets**

| | |
|---|---|
| 1/8-8/8 | as originally filed |

☐ a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing

3. ☒ The amendments have resulted in the cancellation of:
   - ☐ the description, pages
   - ☒ the claims, Nos. 11
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

4. ☒ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).
   - ☒ the description, pages Note 2 from "Furthermore" to "assortment of sounds", Note 3 from "Contrarily" to "wavetables", Note 4
   - ☒ the claims, Nos. 3
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

* *If item 4 applies, some or all of these sheets may be marked "superseded."*

**Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

| | | | |
|---|---|---|---|
| Novelty (N) | Yes: | Claims | 1,2,4-10 |
| | No: | Claims | |
| Inventive step (IS) | Yes: | Claims | 1,2,4-10 |
| | No: | Claims | |
| Industrial applicability (IA) | Yes: | Claims | 1,2,4-10 |
| | No: | Claims | |

2. Citations and explanations (Rule 70.7):

**see separate sheet**

**Re Item V**

**Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

0. Some of the filed amendments were not taken into account because they contain additional subject-matter not present in the application as filed. The following amendments to the description and claims introduce subject matter as defined in Rule 70.2© PCT and have therefore not been accepted.

   - The features described in Note 2, lines 2-3, from ``*Furthermore*" to ``*assortment of sounds*", Note 3, lines 7-12, from ``*Contrarily*" to ``*store wavetables*" and Note 4, all refer to additional advantages of the present application, which go beyond the disclosure of the initially filed description.

   - Claim 3 is not allowable because it introduces subject matter with regard to the originally filed application. Indeed, from the wording of claim 3, it is understood that the ``*control signal*" for periodically modifying the wavelength of ``*said sinusoidal sequences*" relates to the ``*low frequency oscillator*" of the description page 8, whose frequency is defined by TRFREQ. There is however no explicit or implicit indication that the frequency of the ``*low frequency oscillator*" and the fundamental frequency of ``*said sinusoidal sequences*" are proportional, as claimed in the lines 3-5 of claim 3.

1. Because some formulations may be misinterpreted due to lack of clarity (Art. 6 PCT) in the newly filed set of claims, some clarity issues are first indicated in this preliminary examination report.

   The drawings accompanying the description facilitate the understanding of the features claimed from the description. However in contradiction to Rule 6.2 (b) PCT, no reference signs in parenthesis, pointing towards the corresponding parts in the relevant figures of

the description, have been included in the present set of claims.

Claim 1:

The word ``*computing said sequences*" on lines 2-3 is misleading and could be understood as "the process of creating said sequences", which is obviously inconsistent with the description (Art. 6 PCT). Hence, for the purpose of drafting the international preliminary examination report, and in the context of claim 1, the word "computing" will be read and understood as "processing".

The meaning of the sentence on lines 12-16 is obscure because some expressions are grammatically ambiguous (Art. 6 PCT). While drafting this preliminary report, the sentence has been be read as:

*"...and* [based] *on the generation of a random sequence, whose spectrum is modified* **according** *to the time progression of said periodic impulsive deterministic sequence,* **to obtain** *said aleatory sequence, and the smaller the value* **of a sample** *of said periodic impulsive deterministic sequence* ***is,*** *the more said aleatory sequence's energy is concentrated in the lower frequencies"*

2. In the following part of the present preliminary opinion, reference is made to the following documents:
   D1: US5587548
   D2: US5521328

3. D1 discloses a method for synthesising the tones of acoustic musical instruments. It uses an aggregation of envelope weighted excitation tables (D1, columns 7-8 lines 59-13) plus a filtered noise generator (D1, column 8 lines 23-37), in order to create the excitation signal which is fed to a linear resonator comprising a delay line (see D1, figure 15), the latter simulating the body of the instrument and having resonance frequencies independent from the excitation frequencies. It is commonly known in the art that excitation tables may be replaced by a combination of synchronised oscillating functions to avoid digital storage issues. As a consequence, the features claimed on lines 1-9 and 17-22 of claim 1 are not inventive over the prior-art D1.

   Hence, the remaining features claim that

*``said aleatory sequence's synthesis is based on the generation of a periodic impulsive deterministic sequence, whose spectrum is proportional to said harmonic sequence's fundamental frequency, and on the generation of a random sequence, whose spectrum is modified according to the time progression of said periodic impulsive deterministic sequence, to obtain said aleatory sequence, and the smaller the value of said periodic impulsive deterministic sequence's sample is, the more said aleatory sequence's energy is concentrated in the lower frequencies;"* (refer to the clarifications assumed in section 1).

These features (See claim 1, lines 10-16) relate to an *"aleatory sequence synthesis"* (Claim 1, line 10) based on a random sequence, processed using *``a periodic impulsive deterministic sequence"* (Claim 1, lines 10-11) derived from the fundamental frequency of the synchronised oscillating functions (as described above) worded as *``synthesised harmonic sequence"* in claim 1, line 2. The presence of *``a periodic impulsive deterministic sequence"* for generating the random component of a tone, is not disclosed in any of the cited documents in the prior-art. The subject-matter of claim 1 is therefore new (Art. 33(2) PCT).

It is known from document D2 (see figure 11 and column 9 lines 49-65) that an excitation signals can be created from a noise oscillator and multiplied by an envelope signal which represents the tone attack on a "note on" event, thereby simulating the air perturbation during the transitional phase before the tone is established and sustained. Besides this feature, tone fluctuations (tremolo in D2, figure 11 and vibrato in figure 14) are created separately by a low frequency oscillator coupled to an envelope generator (D2, part 47 figures 11 and 14). In this context, one technical problem arising from the prior-art is to simplify the simulation of the frequency fluctuations.

The present application solves the above technical problem by combining the generation of excitation signals producing the periodic frequency fluctuations and the transitional noise, using a *``periodic impulsive deterministic sequence"*. From the state of the art, there is no incentive for generating a *``periodic impulsive deterministic sequence"* that modifies the spectrum of the generated noise in such a way that a small sample value from the *``periodic impulsive deterministic sequence"* results in a concentration of the energy of the output noise excitation to the low frequencies. As a result, the subject

matter of claim 1 is inventive over the prior art D1 in combination with D2 (Art. 33(3) PCT).

Claim 1 therefore seems to meet the requirements of the PCT with regard to novelty and inventive step (Art. 33(2) and (3) PCT). Claims 2 and 4-6, depending on claim 1 and which comply with Art. 6 PCT, do consequently meet the requirements of the Art. 33(2) and (3) PCT as well.

4. The present independent system claim 7 is new over the prior-art because the features of the "aleatory component generator" (lines 6-10 of claim 7) have not been disclosed in the prior-art. It further solves a different technical problem which can be formulated as simulating a regular noise component in a tone synthesis.
There is no hint in the prior art, pointing towards the concentration of the noise component in a short segment of the excitation signal period. The creation of a periodic sequence that controls the concentration of a noise component's energy in a time interval which is shorter than the fundamental period of the main harmonic sequence representing the excitation signal is therefore considered as inventive (Art. 33(3) PCT).

Claims 8-10 depending on the independent system claim 7 consequently fulfil the requirements of Art. 33(2) and (3) PCT as well.

## Description

**Method and electronic device used to synthesise the sound of church organ flue pipes, by taking advantage of the physical modelling technique of acoustic instruments.**

The present patent application refers to a method and electronic device used to synthesise the sound of church organ flue pipes, by taking advantage of the physical modelling technique of acoustic instruments.

Numerous numerical algorithms of physical-mathematical models have been developed based on the examination of the physical behaviour of organ flue pipes and the sound they produce, in order to synthesise the sound emission of aerophone instruments in real time.

Some of These models are based on the mutual symbiotic interaction between a non-linear active section, generally defined as "excitation", and a linear passive section, generally defined as "resonator". An example can be found within the method described in US patent 5,521,328.

The relative numerical algorithm extemporarily produces a sequence that represents the sound of the instrument analysed and translated into a physical model.

The sound is characterised by an initial time interval, defined as "attack transient", during which intensity increases up to a certain value.

The intensity value is indefinitely maintained over time during the second phase, defined as "sustain phase", during which the waveform is approximately periodic.

The analytical characteristics of this waveform, of which the most important is fundamental frequency, depend on each of the parameters that regulate the operation of the numerical simulation.

Being the simulation performed in the time domain instead of the frequency domain because of the presence of numerous non-linear functional blocks, the relation between the set of parameters and each spectral characteristic of the generated sequence is extremely difficult to establish a priori.

The characteristics can be altered by changing the set of parameters, often

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**Note 1) to be inserted line 8, page 2 of the description**

Other physical – mathematical models, as the invention described in US patent 5,587,548, are based on the conjunct usage of PCM audio synthesis and physical – mathematical simulation of parts of the instrument to be reproduced. By analytically decomposing the sound samples of the instruments to be imitated (or of parts of them, as the only resonant body), and dividing what can be easily and cheaply simulated from what is more convenient to store as part of a wavetable, a good compromise between memory usage and computational power necessary to implement such method can be obtained. The excitation sequence, which is preprocessed by the algorithm which simulates part of the acoustical behaviour of the instrument (previously analyzed and mathematically interpreted), is usually stored as a wavetable. However, said method, though requiring computational power for the physical – mathematical simulation, implies to sample, analyze, and pre-compute the sound of each instrument to be reproduced, and said instrument's reproduced sound is in any case bound to said operations, and in particular to what is stored in the wavetables.

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**Note 2) to be inserted line 26, page 2 of the description**

Being not any information derived from real musical instruments' sounds and stored as wavetables, memory usage is quite restrained. Furthermore, an only algorithm which doesn't employ static wavetables as inputs can produce a wider assortment of sounds.

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amplification system and a loudspeaker (8). The synthesis programme, which is the central innovation element of the present patent, includes three sections. Each section has a fundamental function in the numerical simulation of the sound emission of the organ pipe, as shown in Fig. 2.

The block (9) generates a main harmonic sequence (10) composed of a ~~series~~ set of harmonic lines, whose amplitude and frequency conveniently change over time. By using this sequence and taking advantage of part of ~~the~~ its composition, the block (11) generates a pseudoaleatory signal that represents the chaotic component of the sound. The aforementioned sequences are the two input signals of the linear resonator (12) that models the frequency response of the resonant part of the multiple qualities of organ flue pipes, and whose output (13) is the sequence that represents the sound of the organ pipes.

The block diagram of Fig. 3 is a detailed view of the functional blocks of the harmonic component generator (9). The oscillator (14) generates an approximately sinusoidal waveform (16). The fundamental frequency of the waveform changes over time within a range of values comprising the fundamental frequency of the generated musical note. The details of the embodiment of the oscillator and the criterion used to change frequency over time are illustrated below.



The waveform (17) is obtained from the sequence (16) through the non-linear block (15): if the sequence (16) were exactly a sinusoidal sequence

$$x[n] = \sin[\omega_0 n],$$

the sequence (17) would be

$$y[n] = 2\,(\sin[\omega_0 n])^2 - 1 = -\cos[2\omega_0 n] = \sin[2\omega_0 n - \pi/2],$$

that is to say a sinusoid with double frequency than the sequence (16).

Each of the two sequences (16) and (17) is amplified by the relevant multipliers (18a) and (18b), and limited by the functional blocks (19a) and (19b) to values within the ±CLIP1 and ±CLIP2 intervals. The outputs of the blocks (19a) and (19b) are multiplied by two sequences produced by the envelope generators (20a) and (20b), respectively, as illustrated below, and the resulting products are summed to the node (21). The sum is a sequence

* The method exposed in US patent 5,521,328 can be considered as an exemple of this tecnique.

interaction between a non-linear active part, normally defined as *excitation* (55), and a linear passive part, defined as *resonator* (56), according to the scheme of Fig. 17.* In the case of aerophone instruments, the energy contributed to the system is in the form or sound pressure and the signal produced is the progression of the sound pressure wave irradiated by one or more suitable points of the resonator. The waveform p(t) is the progression of the air pressure that the performer (or the bellows, in the case of a church organ) exercises on the instrument mouthpiece. According to this progression and to the progression of the pressure w(t) in a suitable point inside the resonator, an oscillating acoustic pressure e(t) injected in the resonator is generated. Once the sustain phase has been reached, the pressure e(t) has the same fundamental frequency as the pressure w(t). Being linear (except for very special operation modes), the resonator can be described with an impulse response r(t), which generates the return signal w(t) and an impulse response h(t), which generates the output signal y(t). The latter is the time progression of the sound emission of the instrument. Being it a numerical simulation performed in the time domain instead of the frequency domain, the fundamental frequency of the oscillation on which the system stabilises, once the sustain phase has been reached, is extremely difficult to predict mathematically. This depends on the fact that the frequency depends on the time progression of the forcing signal e(t), and not only on the frequency values in which the amplitude spectrum of the impulse response of the resonator has the relative maximum values. In fact, any type of harmonic oscillator (electronic, mechanical, etc.) has this characteristic. With regard to wind instruments (including organ pipes), it is sufficient, for example, to increase the sound pressure to obtain an increase of the fundamental frequency of the acoustic wave, in addition to an intensity increase, although the characteristics of the resonant part remain unchanged.

Another inevitable characteristic of the oscillating systems illustrated in Fig. 17 is the unpredictability of the phase of the generated signal, once the sustain phase has been reached. Since the waveform p(t) used to stimulate the system is partially chaotic, and in any case it does not contain any

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**Note 3) to be inserted line 6, page 13 of the description**

The current literature proposes, as e.g. in US patent 5,587,548, an alternative technique which is known as *commuted synthesis*, based on excitation wavetables and resonant filters, being the latter used to simulate the acoustical behaviour of an instrument's linear and passive part. In such a case, with an adequate sampled sound's analysis and optimization, a good compromise is found between the necessary amount of memory for the wavetables and the necessary computational power to implement the physical – mathematical algorithm which corresponds to the instrument's resonant parts. Contrarily, a system whose excitation isn't bound to wavetables, as in the case of the harmonic component generator (9), makes it possible to obtain a greater variety of excitations, dependently on the sequence of operations performed on the sinusoidal sequence (16), and dependently on the set of parameters of Fig. 3. Furthermore, a quite smaller amount of memory is required to store said parameters than to store wavetables.

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**Note 4) to be inserted line 14, page 13 of the description**

The originality of the system mainly consists in the utilization of two independent envelopes (20a) and (20b) to provide different time progressions to the main frequency and the first overtone frequency, being this a characteristic behaviour of many flue pipes' families.

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therefore the sequence OUT separates until it re-joins at point $t_1$, after which the sequence IN remains constant. In the instant $t_2$ the excessive inclination of the sequence IN causes the immediate separation of the sequence OUT up to the re-conjunction point $t_4$. With respect to a linear filter, the advantage of the "RATE LIMITER" is the elimination of possible discontinuities of the aleatory sequence, while still maintaining a sufficient bandwidth, being such discontinuities ~~which are~~ extremely unpleasant for the human hearing. This aspect represents the originality of the "RATE LIMITER".

The non linear block (42) can be replaced with any functional block whose effect on the structure "NOISE BOX" of Fig. 11 is the quantitative resonance variation generated by the structure, according to a periodic progression.

As regards the linear resonator (12), the physical considerations that involve the choice of the functional blocks of Fig. 15 are described herein. The resonant part of an organ pipe, defined as *pipework*, can be mathematically described, in the most elementary way, with a "*comb*" filter $1/(1 - FBK \cdot z^{-N})$, in which the feedback coefficient FBK is related to the loop gain of the filter and the parameter N is inversely proportional to the first resonance frequency of the same. The more complex resonator of Fig. 15 derives from this base, which is very used in the field of audio digital processing. Among the elements of the resonator, the function of the delay line (54) appears evident. The response in module of the low-pass filter (47) is designed so as to consider the different energy losses suffered by the various harmonic components during their transit along the pipework, while the high-pass filter (49), whose cut-off frequency is lower than the fundamental frequency of the resonator, completely eliminates the continuous component of the stationary wave, to take into account the fact that the average acoustic pressure inside a pipework is approximately equal to the external pressure. Because of the envelope generator (50), during the first operation phase of the resonator, the loop gain of the system is moderately overabundant with respect to the value once the sustain phase has been reached, in order to obtain a faster initial energy accumulation in the resonator, that is to say a faster attack transient of the generated sound. The sign of the factor TFBK (53) is especially important:

**New set of claims**

1) Method suitable for church organ flue pipes' sound synthesis which consists in synthesizing a harmonic sequence, synthesizing an aleatory sequence, and computing said sequences by means of a closed loop of linear functional blocks, characterised by the fact that:

- said harmonic sequence's synthesis is based on the generation of a first sinusoidal sequence whose frequency, dependently from information derived from musical means, is the fundamental frequency of said harmonic sequence, and on the generation of a second sinusoidal sequence, whose frequency is a multiple of said first sinusoidal sequence's frequency;
- said aleatory sequence's synthesis is based on the generation of a periodic impulsive deterministic sequence, whose fundamental frequency is proportional to said harmonic sequence's fundamental frequency, and on the generation of a random sequence, whose spectrum is modified accordingly to the time progression of said periodic impulsive deterministic sequence obtaining said aleatory sequence, and the smaller is the value of said periodic impulsive deterministic sequence's sample, the more said aleatory sequence's energy is concentrated in the lower frequencies;
- said closed loop of linear functional blocks includes input nodes to process said harmonic sequence and said aleatory sequence, and a delay line to give said closed loop's impulse response a set of resonance frequencies which are independent from

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said harmonic sequence's and said periodic impulsive deterministic sequence's fundamental frequencies.

2) Method as described in claim 1, characterized by the fact that said harmonic sequence's synthesis includes envelopes' generation, to give independent wave envelopes to two sequences derived from said two sinusoidal sequences, to resemble the first overtone frequency's time progression during the attack transient of flue pipes' sound.

3) Method as described in claim 1, characterized by the fact that said harmonic sequence's synthesis includes the synthesis of a control signal, whose function is the periodical modification of the wavelength of said sinusoidal sequences, being said modification made with a frequency which is proportional to said sinusoidal sequences' fundamental frequency.

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4) Method as described in claim 1, characterized by the fact that the difference between said aleatory sequence's two consecutive samples is limited accordingly to the values of said periodic impulsive deterministic sequence's samples.

5) Method as described in claim 1, characterized by the fact that said aleatory sequence is processed by a closed cycle comprising delay lines, being said closed cycle characterized by a time-variant loop gain.

6) Method as described in claim 1, characterized by the fact that said closed loop of linear functional blocks corresponds to the pipework of flue pipes, and characterized by the fact that said delay line shapes said flue pipes' tone, without any interdependency with the fundamental frequency of the sequence processed by said closed loop of linear functional

blocks, allowing to model pipeworks whose length is commensurable or non-commensurable with said harmonic sequence's fundamental period.

7) Electronic device for the synthesis of sounds according to the method described in claim 1, characterized by the fact that it comprises:

- a first section defined as "harmonic component generator" (9) that autonomously synthesizes a "main harmonic sequence" (10), which simulates the time progression of the acoustic waves injected by the air flow into the flue pipe's pipework;
- a second section defined as "aleatory component generator" (11) which generates a random sequence and a periodic impulsive sequence whose samples' value controls the spectrum of said random sequence, so that the most of the energy of said random sequence is concentrated in a time interval which is shorter than the fundamental period of said "main harmonic sequence" (10);
- a closed loop section defined as "linear resonator" (12) comprising a delay line and linear filters, which receives as inputs the two sequences generated by said "harmonic component generator" (9) and said "aleatory component generator" (11), and produces as output a sequence (13) that represents the product of said electronic device for the synthesis of sounds.

8) Electronic device for the synthesis of sounds as described in claim 7, characterized by the fact that said "harmonic component generator" (9) comprises two frequency generators which produce two periodic sequences whose fundamental frequencies have a constant ratio and whose envelopes are independent.

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9) Electronic device for the synthesis of sounds as described in claim 7, characterized by the fact that said "harmonic component generator" (9) comprises a generator which produces an aleatory sequence whose samples change their random value with a frequency proportional to the fundamental frequency of said "main harmonic sequence" (10).

10) Electronic device for the synthesis of sounds as described in claim 7, characterized by the fact that said "aleatory component generator" (11) comprises delay lines and a rate limiter forming a closed loop.

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